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Infestation to fish and shellfish by phytotoxins, with reference to countermeasures

Kenehisa HASHIMOTO* and Tamao NOGUCHI*

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Proceedings of the Japanese Association of Mycotoxicol. No. 25, 1987

Kanehisa HASHIMOTO and Tamao NOGUCHI : Infestation to fish and shellfish by phycotoxins, with reference to countermeasures

Paralytic shellfish poison (PSP), diarrhetic shellfish poison (DSP), and ciguatera poison are some of the phycotoxins infecting fish and shellfish, causing poisoning among people as well as death among fish. In all cases, some specific planktons produce the poison which poisons the plankton feeder bivalves. Of the above poisons, PSP has caused contamination not only in Japan but in Southeast Asia, Europe and America as well, and DSP contamination has become a similar concern in Japan and Europe (more particularly in the countries bordering on the North Sea). Meanwhile, the ciguatera poison affects the populations of the equatorial regions as well as those of the outlying islands of the adjacent subequatorial regions, and causes much trouble with regard to the ensuring of animal proteins. We will consider here mainly the countermeasures adopted in Japan to meet the contamination by the three aforementioned poisons.

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1. Paralytic shellfish poison

PSP is a shellfish poison with a long history in North America and Europe. It causes food poisoning characterized by paralysis and has brought about numerous deaths.

In Japan[1]) a red tide of Protogonyaulax catenella which it one of the poison-producing planktons was observed for the first time in 1975. The presence of PSP was incertained. The event triggered reports of PSP poisering by bivalves from all regions (Table 1). Meanwhile, there were repeated occurences of red tide caused in April-November 1983 by the poisonous dinoflagellate Pyrodinium bahamense var compressor in Southeast Asia.[2]) Bivalves were poisoned over wide areas and there were numerous cases of food poisoning, some causing death in the Philippines and in Thailand. In 1986 PSP poisoning broke out for the first time in Taiwan[3]) and in South Korea (Table 2).

Aside from the above 2 species of PSP - causing plankton, one knew also protogonyaulax tamarensis, the blue algae Aphanizomenon flos-aquae[1]) and such. Very recently the power of producing PSP was also observed in Gymnodinium catenatum[4]). In Japan the main sources of trouble are P. catenella and P. tamarensis. The bivalves poisoned by PSP are the scallop Patinopecten yessoensis, the akazara Chlamys nipponensis akazara, the Pacific oyster Crassostrea gigas, the short-necked clam Tapes (Amygdale) japonica and such. Sometimes the prochordate maboya Holocynthia roretzi is poisoned and causes actual food poisoning[1]). The poisoning of shellfish by P. catenella supposes the formation of red tide. However, P. tamarensis causes generally the poisoning of shellfish at an extremely low density. The reasons for the differences are not known. The poison accumulates mainly in the midgut gland of the bivalves or in the pancreas and liver of maboya. Almost no poison or no poison at all is found in the adductor muscle even when the midgut gland is conspicuous by poisoned.

Until around 1975, PSP was deemed to be a saxitoxin. Further research has established that it is composed of 10 components divided into the two main

saxitoxin and the gonyautoxin groups. Most of the structure has been elucidated and the basic skeleton is common (Fig. 1).

As for the measures taken against PSP poisoning[5]), monitoring of the main shellfish production sites had already been organized in the US and Canada where much contamination damage is caused by these phytotoxins and poisoning prevention has been planned. That is, samples are regularly collected from those sites and toxicity is checked by the PSP quantitative determination method (AOAC method) utilizing mice. If the toxic power of the shellfish exceeds 80 μg of saxitoxin/100 g of edible part, harvest, transport, sale and so on intended for live consumption are prohibited. The policy in Japan is more or less similar. Sample shells are collected from the main production sites and the toxicity of the shells is examined according to the officially stipulated PSP quantitative determination method[6]). If 4 MU/g of edible part (corresponding roughly to the above 80 μg saxitoxin/100 g of edible part) is found, shipments of the shellfish are restricted[7]). If the shellfish is processed for canning, there is a decline in PSP toxicity concomitant to the heating, and it would seem that the regulations are relaxed. Even in this case it is indispensable to check the toxicity of the manufactured goods.

2. Diarrhetic shellfish poison

DSP is a phytotoxin which was discovered 10 years ago in the process of studying the cause of a food poisoning whose main symptom was diarrhea brought about by mussels* from the Sanriku region in the summer, and which like PSP is

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*Translator's note: murasakiigai; Mytilus edulis LINNE; same hereafter for "mussel" used alone.

mode of numerous components (hereafter). There were subsequent reports of large-scale food intoxication caused by this poison in various western European countries bordered by the North Sea such as the Netherlands, France and Spain as well as from Chili[8]). In Japan the plankton-producing DSP is identified as the dinoflagellate Dinophysis fortii. D. acuminata and D. caudata are also objects of suspicion. Meanwhile, D. acuminata in the Netherlands and Spain as well as D. acuta in Norway and Chili are believed to be causative agents. Prorocentrum lima which is a type of dinoflagellate produces also okadaic acid (see Fig. 2) which is one DSP component[8]).

DSP is made of about 10 components such as the dinophysistoxin and pectenotoxin groups. Most of the structure has already been elucidated (Fig. 2)[8]). As for DSP too, various bivalves have become poisoned. These are represented by scallops, mussels and such. Depending on the region, blue sea mussels (Mytilus coruscum), kotamagai (Gomphina (Macridiscus) melanaegis, Chosen hamaguri (Meretrix lamarckii) and such have become a problem. Even at the very low concentration of two cells/L, D. fortii renders shellfish poisonous. The poison is located in the midgut gland.

At the present time, the same monitoring system adopted is practically the same as for PSP at the main shellfish production sites. When the toxicity exceeds 0.05 MU/g of edible part, regulating measures are established for shipments intended for live consumption . As the poison is located in the midgut gland as mentioned before there are no particular regulations at the raw-material shellfish stage when the midgut gland is removed during processing.

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3. Ciguatera poison

Ciguatera is a general name for the low-mortality poisoning caused by coral reef fish taken in the tropical and subtropical regions of the Pacific and in the Caribbean sea. One says also: "Ciguatera poisoning". The unique symptoms are to induce mistaking high temperature for low temperatures and to cause the feeding of touching dry ice when the hand is put in water. Multiple toxins such as ciguatoxin (CTX), maitotoxin (MTX), scaritoxin are involved in the present poisoning. CTX, the main toxin is together with MTX produced by the sedentary dinoflagellate Gambierdiscus toxicus. This plankton grows in high density on the surface of calcareous algae and such. It may according to reports exhibit a state close to monoculture in which more than 500,000 cells are attached to 1 g of marine algae. The poison travels along the food chain from the plankton to the herbivorous and carnivorous fish to finally cause problems in humans. Generally, toxicity is highest in the liver, followed by the other organs and then by the muscles. There are not few cases in which food poisoning was caused by the ingestion of muscle only.[10])

The smallest lethal quantities (LD_{50}) of CTX and of MTX are 0.45 μg/kg of mouse and 0.17 μg/kg of mouse respectively. The strengths are respectively 20 and 60 times the strength of STX (100 μg/kg of mouse). However, the structures of both toxins are still unknown.

To counter the ciguatera danger, the food health inspectors monitor every market to make sure that no toxic type of suspicious marine product becomes admixed to the food distribution. As soon as a toxic product is found, it is disposed of. A related problem is that the present mouse tests

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are not too sensitive with regard to CTX and such, and that their specificity is low. One is looking forward to a detection method which is sensitive, rapid and inexpensive.

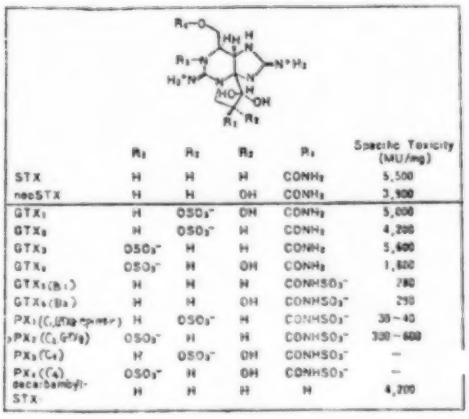
Table 1. PSP infestation to bivalves in Japan

Place	Date	Bivalves infested	Causative plankton	Water temperature (°C)
Funka Bay, Hokkaido	Jun.–Oct., 1978	Scallop	*P. catenella Funka*	8–14 (Middle layer)
	Apr., 1979–Jan., 1980	Mussel		
	Apr.–Nov., 1980			4–15 (Middle layer)
	Apr.–Dec., 1981			
	Mar.–Oct., 1982			
	May–Dec., 1983			
	Mar., 1984			
Ofunato Bay, Iwate Pref.	May, 1976	Scallop	*P. excavata OF 1*	10–15 (Middle layer)
	May, 1977	Akazara scallop	& *P. catenella*	
	May, 1978			
	Mar.–Dec., 1979			
	Apr.–Dec., 1980			
	Feb., 1981–Jan., 1982			
	Mar., 1982–Jan., 1983			
	Jun.–Sep., 1983			
	Mar.– 1984			
Ise Bay, Mie Pref.	Apr.–May, 1976	Short-necked clam	*P. catenella*	
	Jan., May, 1977	Mussel, "Isoshizimi"	(Red tide)	
Owase Bay, Mie Pref.	Jan.–Feb., 1975	Short-necked clam	*P. catenella*	15.4 (Surface layer, bottom layer)
		Mussel	(Red tide)	
Wakanoura Bay, Wakayama Pref.	Jun., 1980	*Chlamys nobilis*	*P. catenella* (Red tide)	
Tanabe Bay, Wakayama Pref.	Jun.– 1981	*Chlamys nobilis*	*P. catenella* (Red tide)	17–22 (Surface layer)
	May–Jul., 1982		〃	
	Apr.–Jul., 1983		〃	
Seto Inland sea				
Kagawa, Okayama Pref.	Jun., 1976	Mussel	*P. catenella*	
Kagawa, Tokushima Pref.	Apr., 1981	Oyster, Short-necked clam, Mussel	*P. tamarensis*	
Kagawa Pref.	Jul., 1983	Mussel	*P. catenella*	
Komatsushima Bay, Tokushima Pref.	Jun., 1976		*P. catenella* (Red tide)	
Tachibana, Thubakidomari Bay, Tokushima Pref.	May, 1979	Short-necked clam	*P. catenella* (Red tide)	15
	Jun., 1982	Short-necked clam, Mussel	〃	
Senzaki Bay, Yamaguchi Pref.	Jan.–Feb., 1979	Oyster	*P. catenella*	11–13
	Dec., 1979–Jan., 1980			10
	Dec., 1981–Jan., 1982			
	Dec., 1982–Jan., 1983			
	Dec., 1986–		*G. catenatum* (?)	13
Kitaura Miyazaki Pref.	Mar., 1982	Short-necked clam, *Chlamys nobilis*	*P. catenella* (Red tide)	

Table 2. Incidences of paralytic shellfish poisoning in Japan and adjacent areas

Date	Causative shellfish	Location of collection	Number of patients (Deaths)	Composition of PSP*
Japan :				
Jul., 1948	Short-necked clam, *Tapes japonica*	Toyoha-shi, Aichi Pref.	12 (1)	?
May, 1961	Scallop, *Chlamys nipponensis akazara*	Ofunato Bay, Iwate Pref.	20 (1)	?
Feb., 1962	Oyster, *Crassostrea gigas*	Miyazu, Kyoto	42 (0)	?
Jan., 1979	Oyster, *Crassostrea gigas*	Senzaki, Yamaguchi Pref.	16 (0)	GTXs, STXs
Apr., 1979	Mussel, *Mytilus edulis*	Asahikawa, Hokkaido	3 (1)	
May, 1982	Ascidian, *Holocynthia roretzi*	Ofunato, Iwate Pref.	2 (0)	GTXs, STXs
Taiwan :				
Jan., 1986	Purple clam, *Soletellina diphos*	Tungkang, Pingtung Pref.	30 (2)	GTXs, STXs
Korea :				
Apr., 1986	Mussel, *Mytilus edulis*	Pusan	15 (2)	GTXs, STXs

* Refer to the legend for Fig. 1.



	R_1	R_2	R_3	R_4	Specific Toxicity (MU/mg)
STX	H	H	H	$CONH_2$	5,500
neoSTX	H	H	OH	$CONH_2$	3,900
GTX_1	H	OSO_3^-	OH	$CONH_2$	5,000
GTX_2	H	OSO_3^-	H	$CONH_2$	4,200
GTX_3	OSO_3^-	H	H	$CONH_2$	5,400
GTX_4	OSO_3^-	H	OH	$CONH_2$	1,600
$GTX_{5(B_1)}$	H	H	H	$CONHSO_3^-$	780
$GTX_{6(B_2)}$	H	H	OH	$CONHSO_3^-$	290
PX_1 (C_1/C_2 epimer)	H	OSO_3^-	H	$CONHSO_3^-$	30~40
PX_2 (C_1/C_2)	OSO_3^-	H	H	$CONHSO_3^-$	300~600
PX_3 (C_4)	H	OSO_3^-	OH	$CONHSO_3^-$	–
PX_4 (C_4)	OSO_3^-	H	OH	$CONHSO_3^-$	–
decarbamoyl-STX	H	H	H	H	4,200

Fig. 1. Structures of PSP components
STX = saxitoxin; GTX = gonyautoxin; PX = protogonyautoxin.

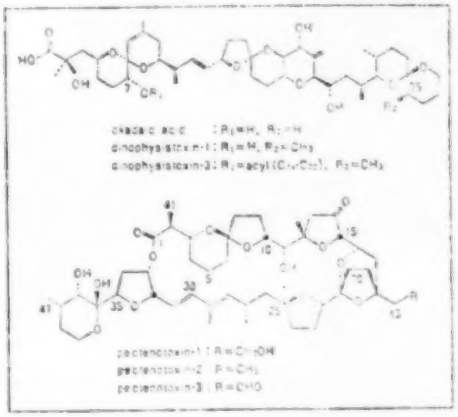


Fig. 2. Structures of DSP components

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